ESC201T : Introduction to Electronics

Lecture 24: Power Supply (part-2)

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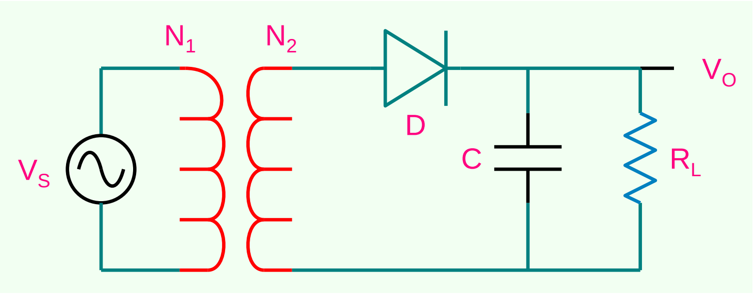
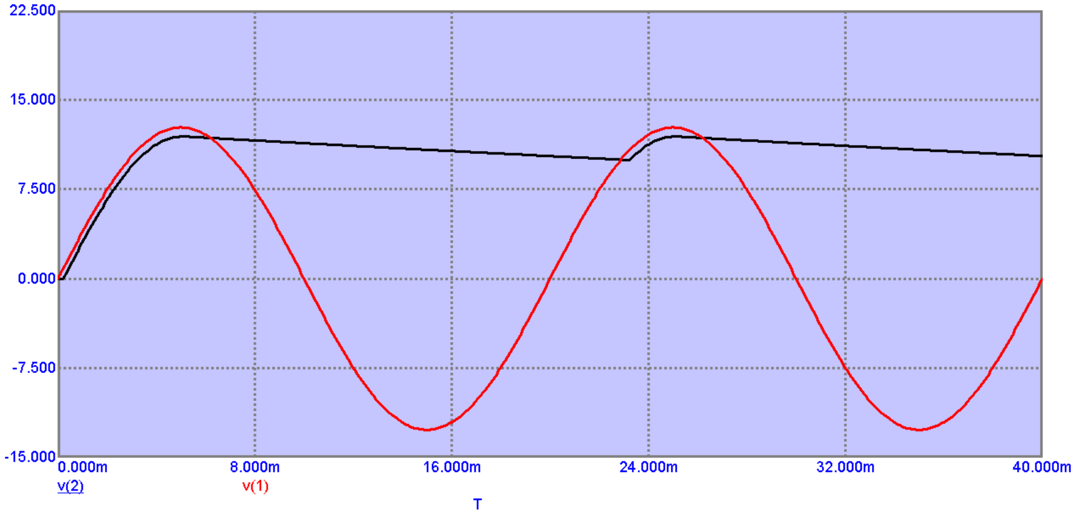
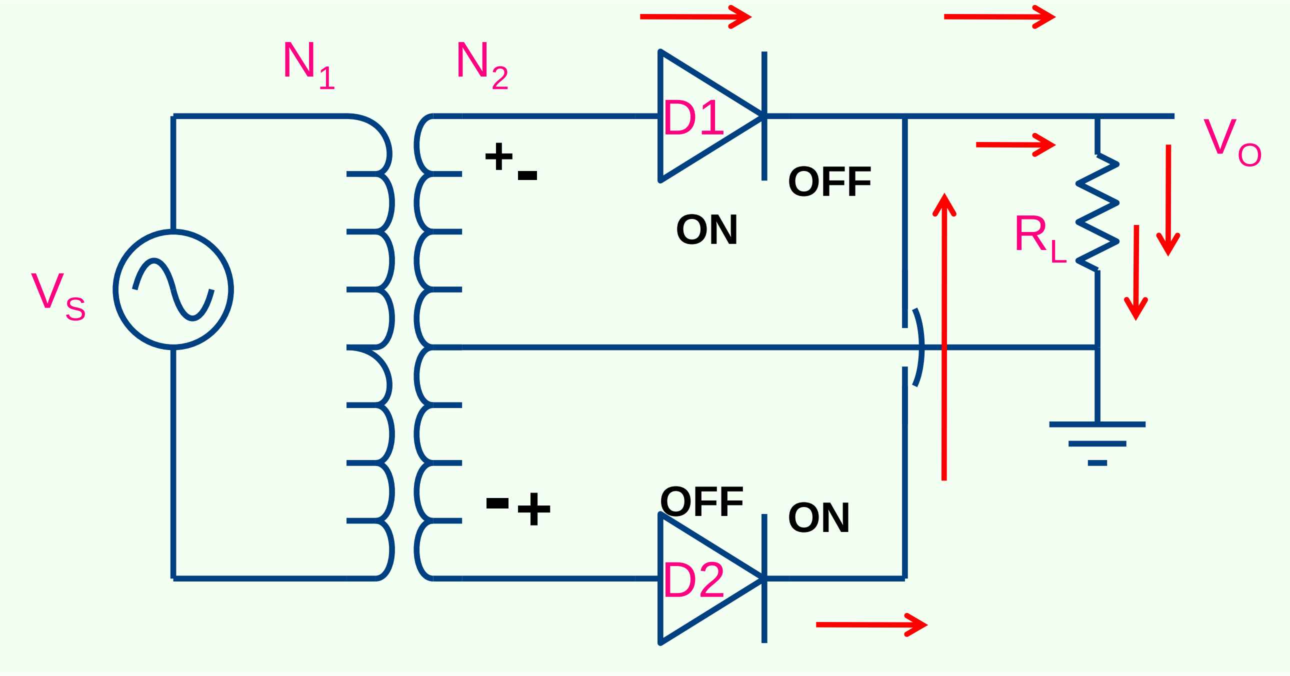
Dept. of EE, IIT Kanpur

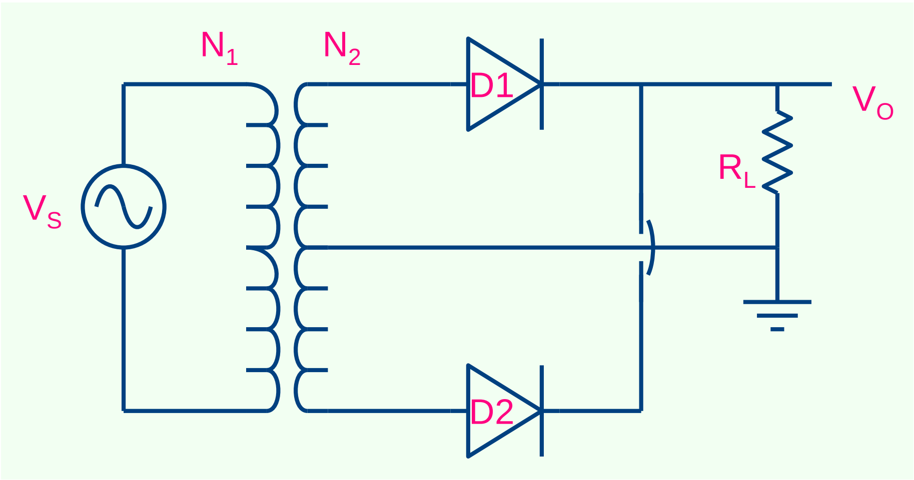
Full wave Rectifier

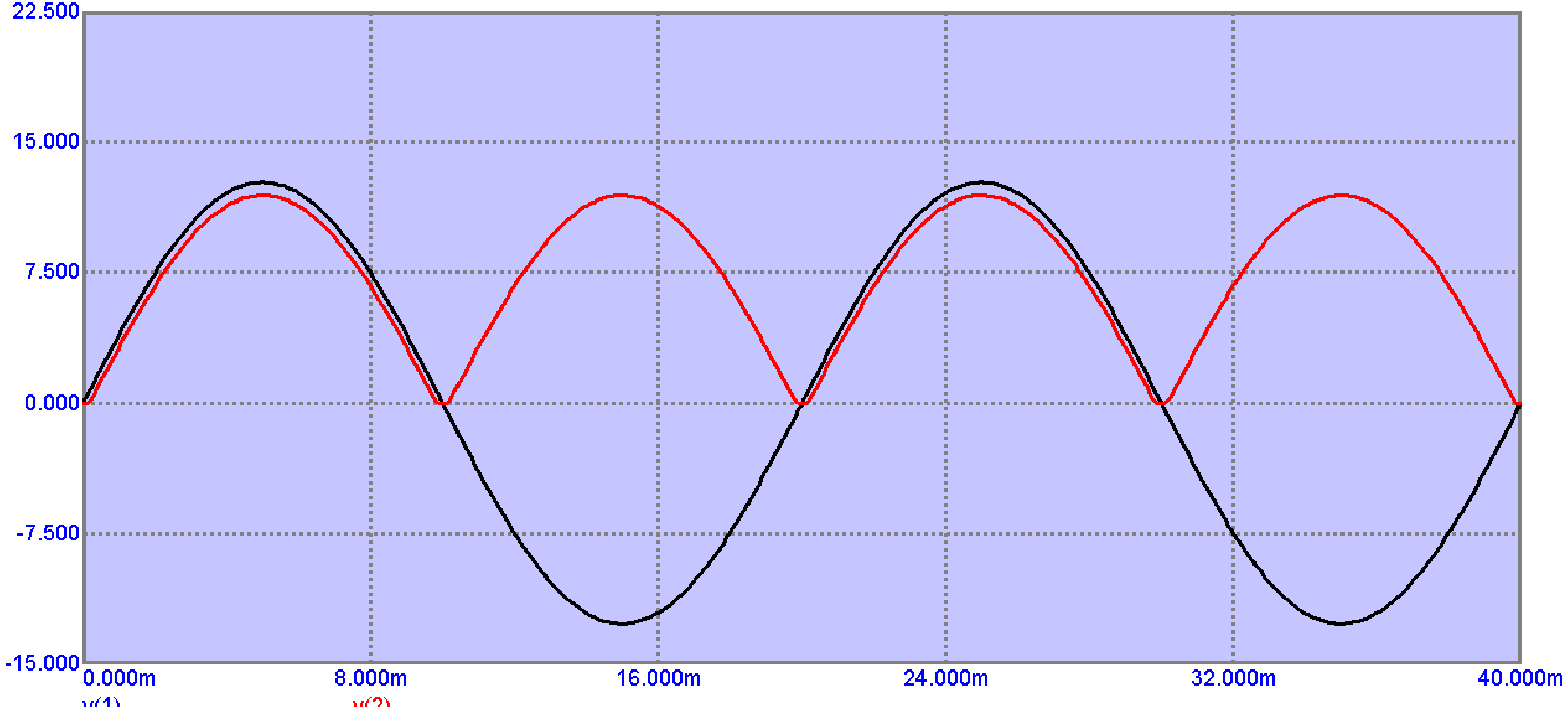


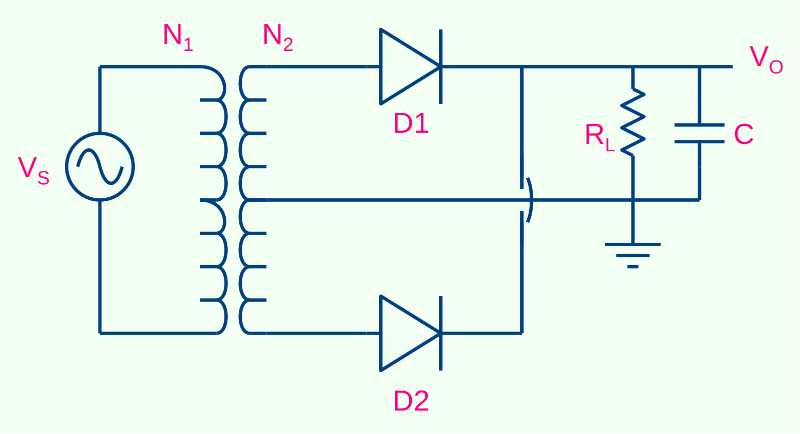
$$V_r \cong \frac{V_M}{fR_L C}$$

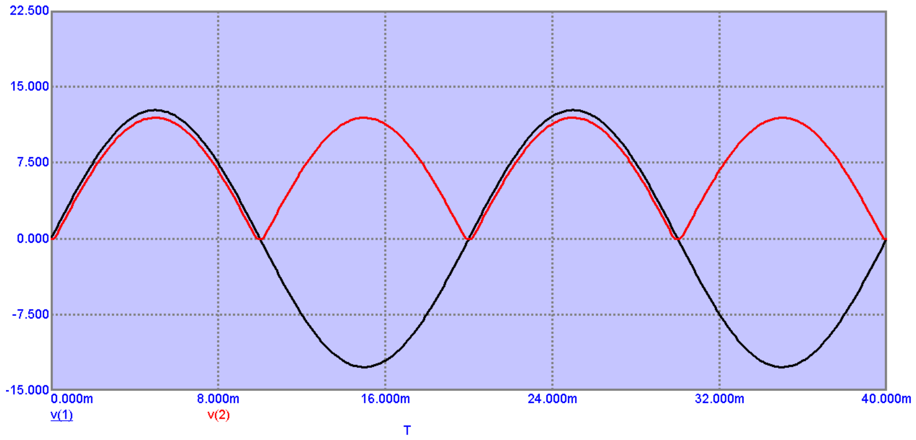


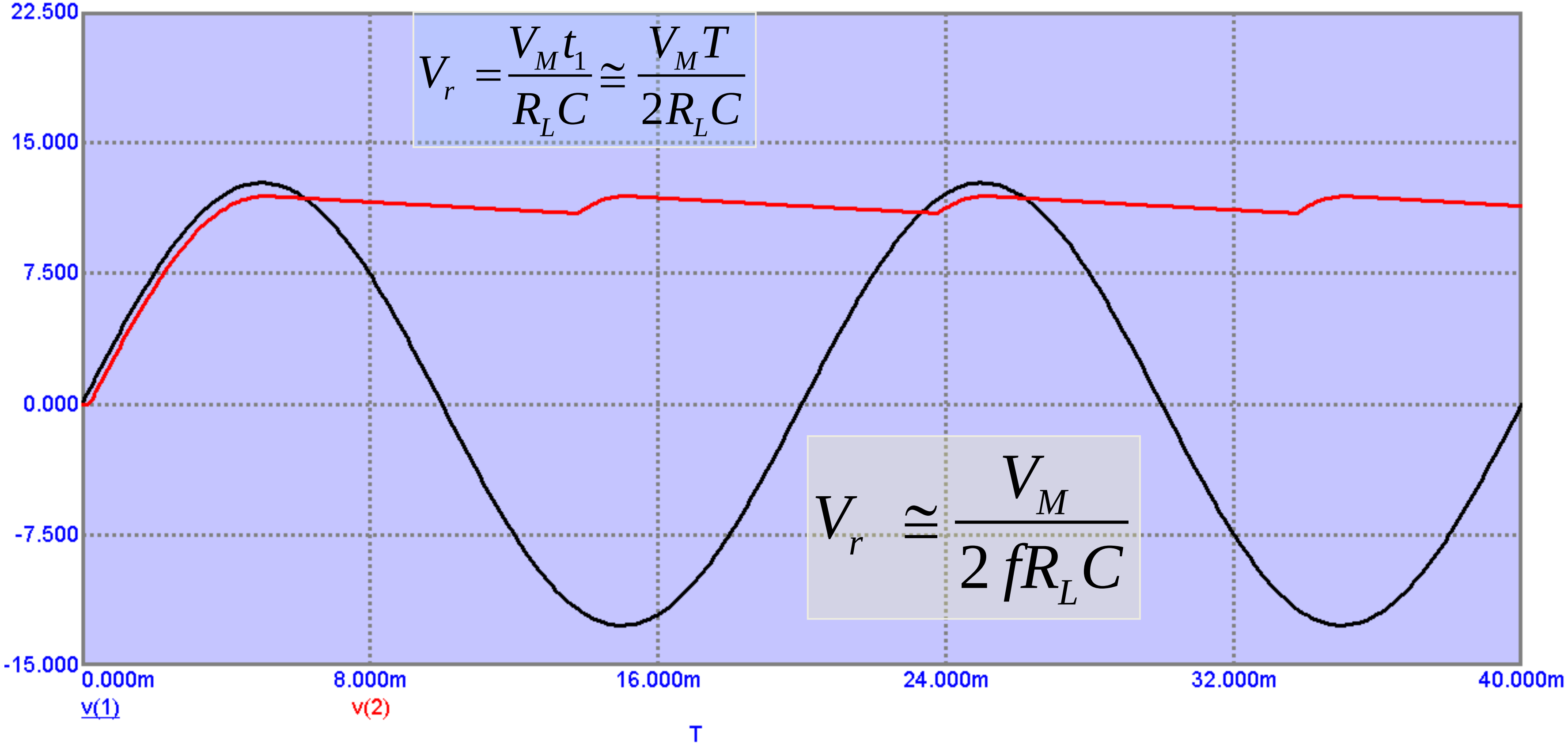



N1
N2
D1
D2
VO
RL
VS


22.500
15.000
7.500
0.000
-7.500
-15.000
0.000m
8.000m
16.000m
24.000m
32.000m
40.000m
v(1)
v(2)





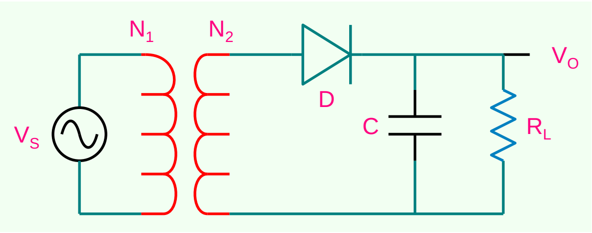


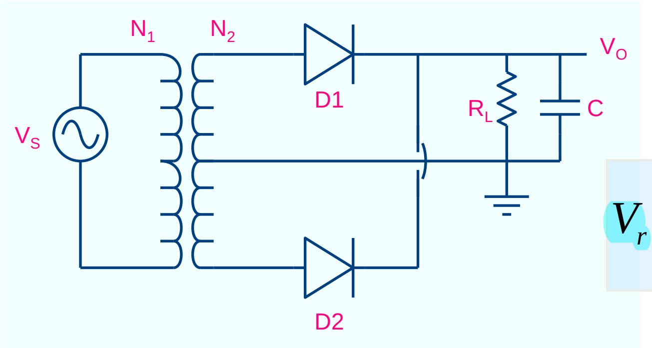
$$V_r = \frac{V_M t_1}{R_L C} \cong \frac{V_M T}{2 R_L C}$$

$$V_r \cong \frac{V_M}{2\,f R_L C}$$

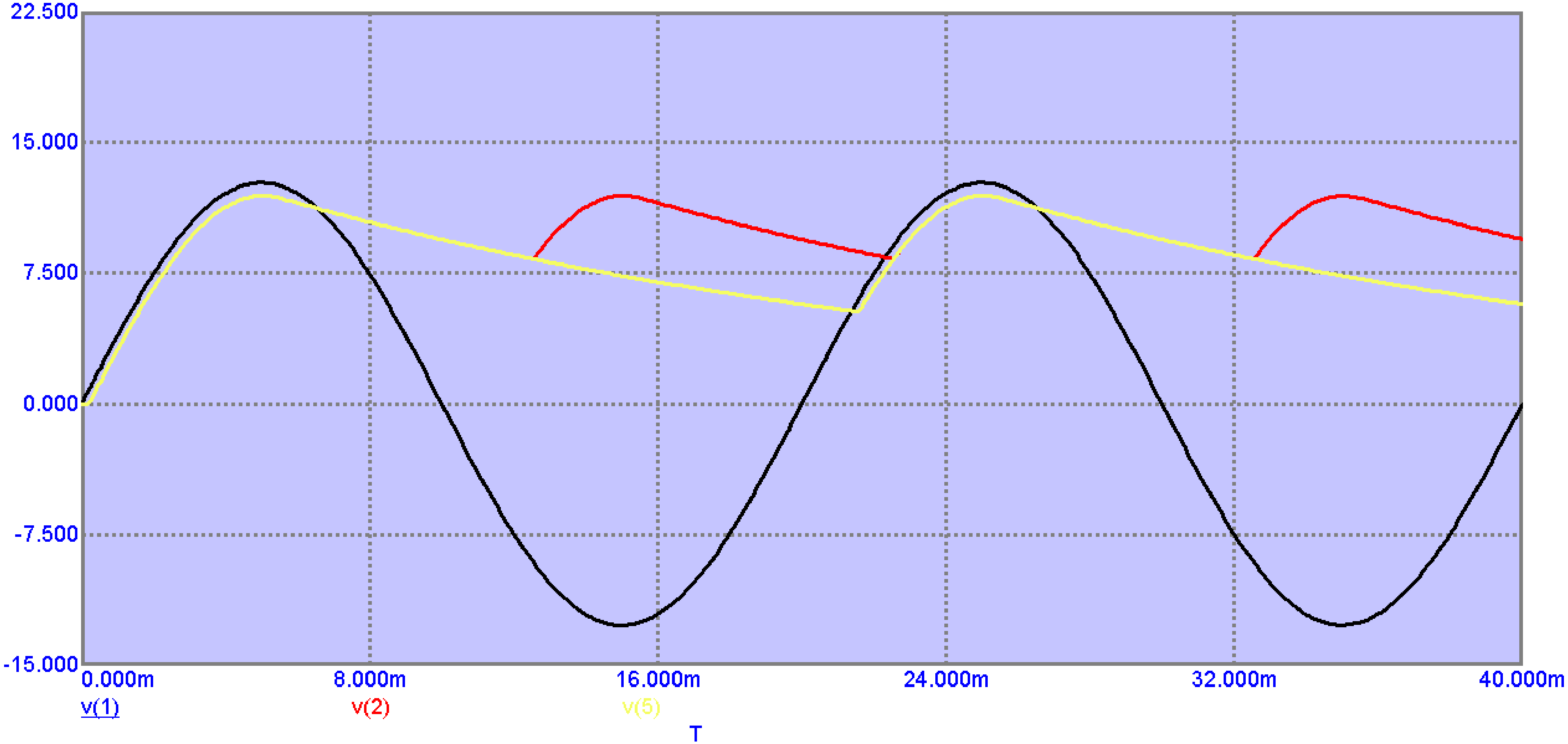
Comparison of full and half Wave Rectifier

$$V_r \cong \frac{V_M}{fR_LC}$$

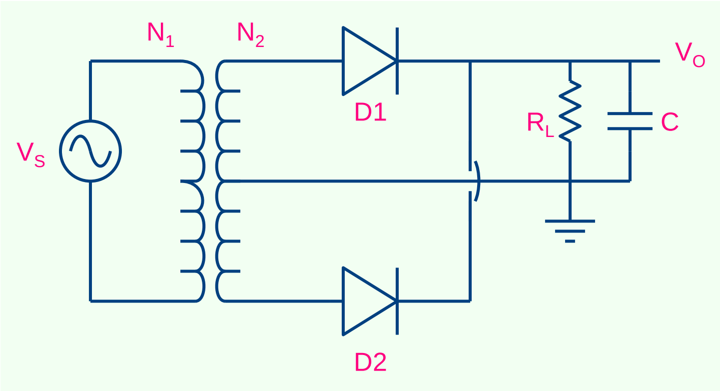


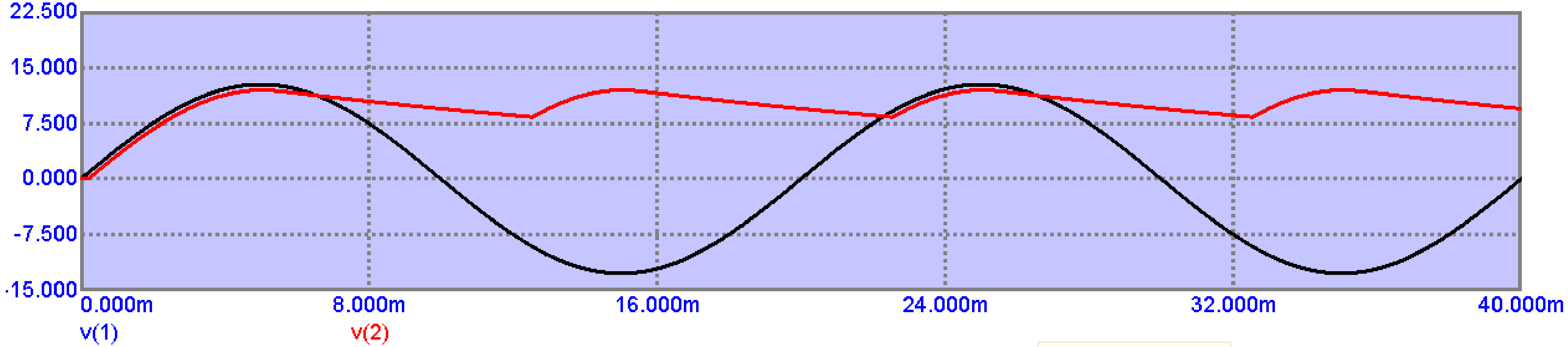


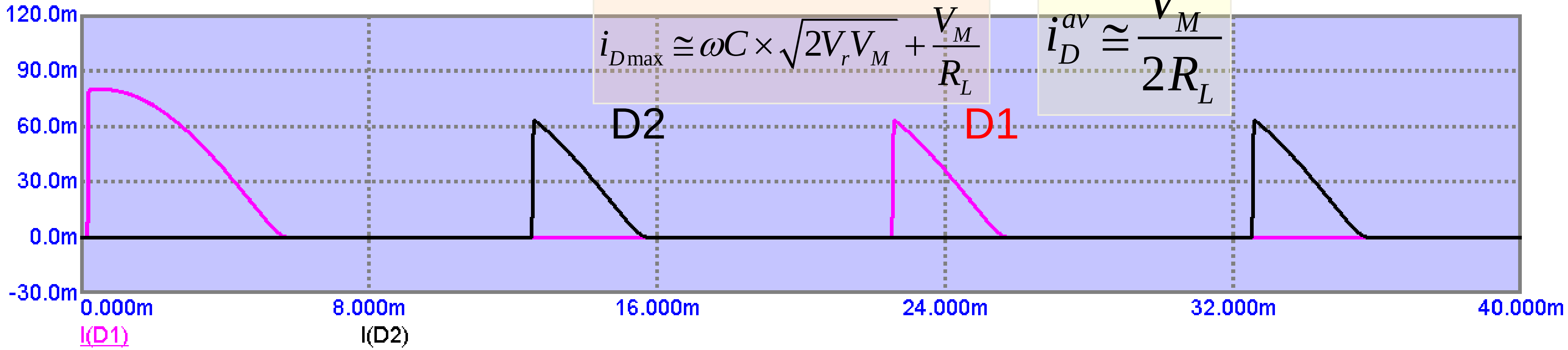
$$V_r \cong \frac{V_M}{2\,fR_LC}$$



Diode Currents in Full wave Rectifier



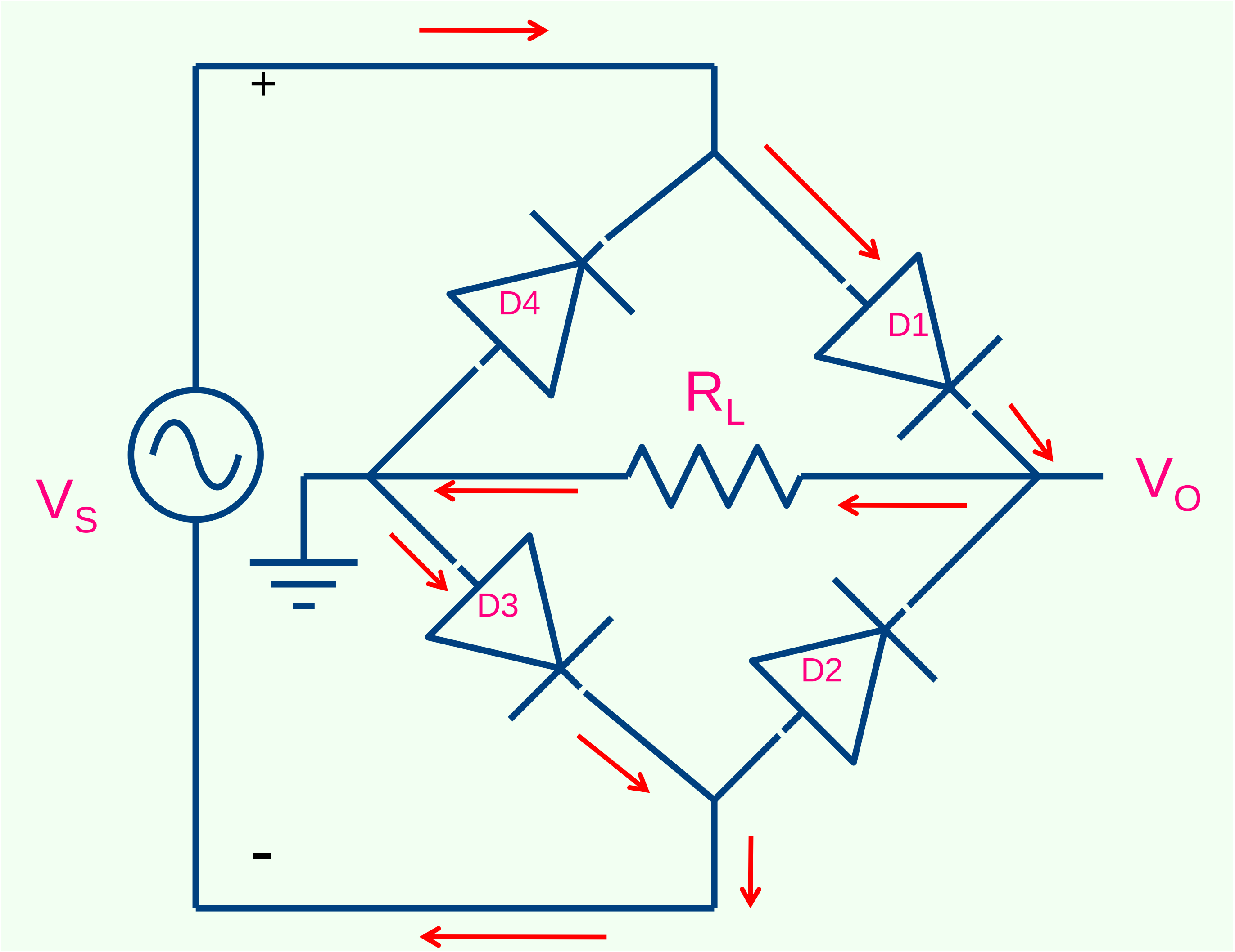


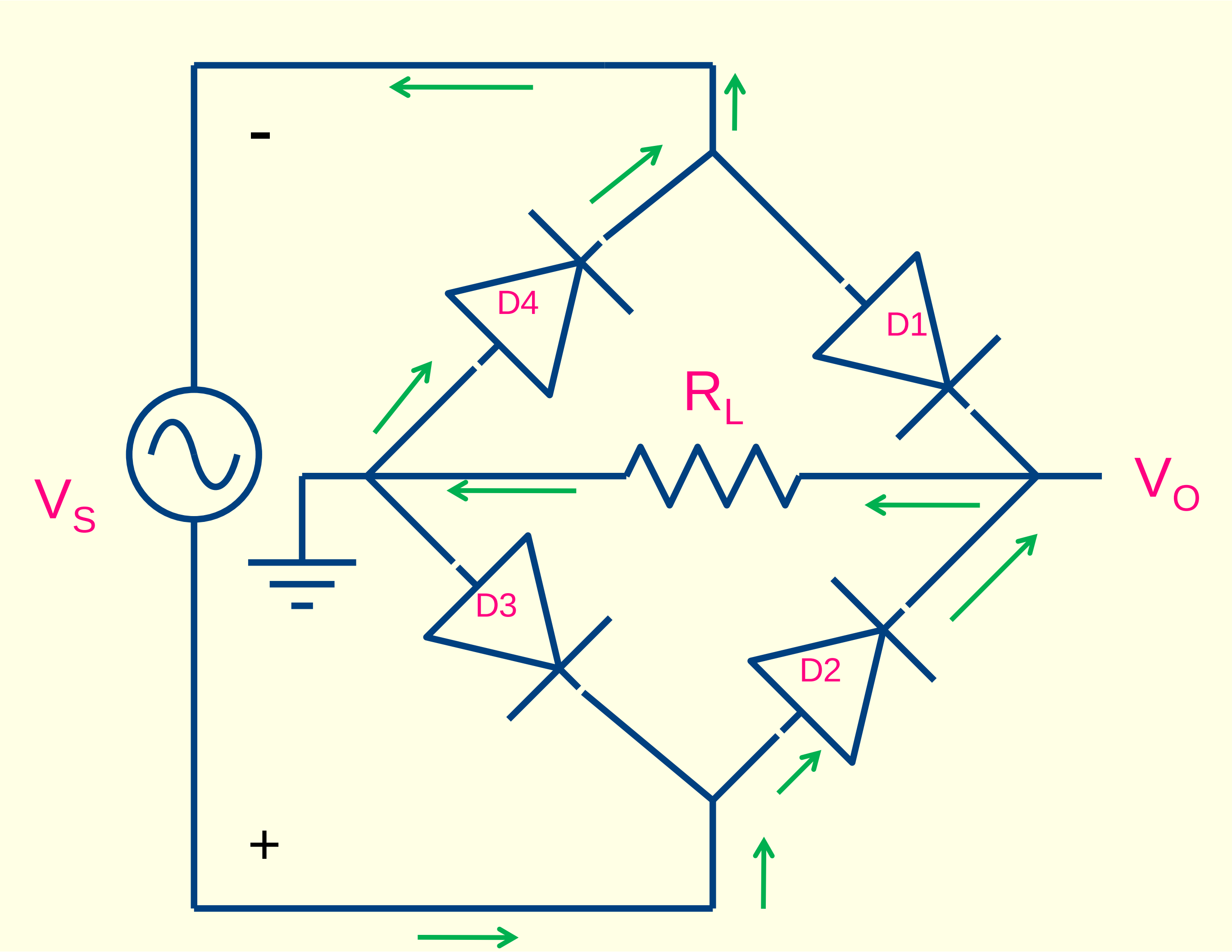


$$i_{D\max} \cong \omega C \times \sqrt{2V_r V_M} + \frac{V_M}{R_L}$$

$$i_D^{av} \cong \frac{V_M}{2R_L}$$

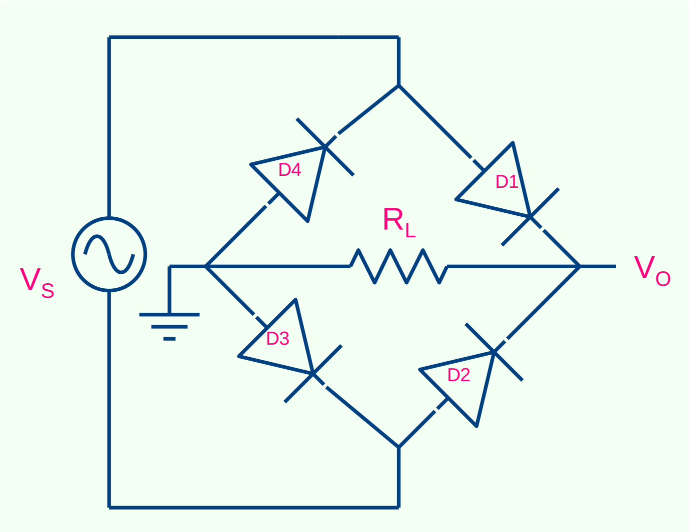
Bridge Rectifier

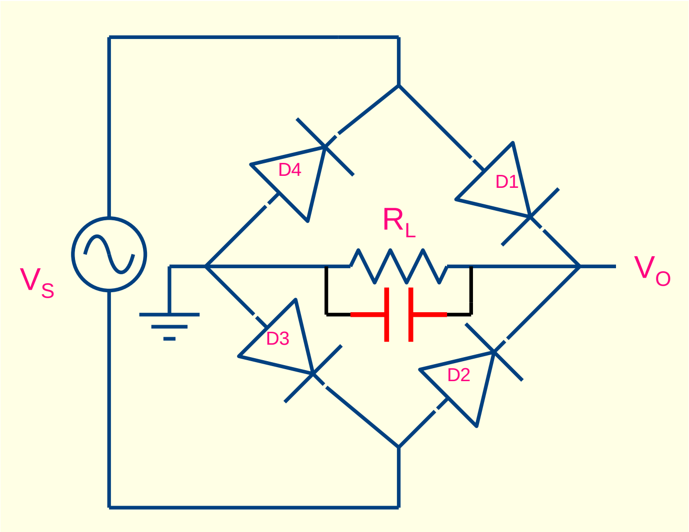


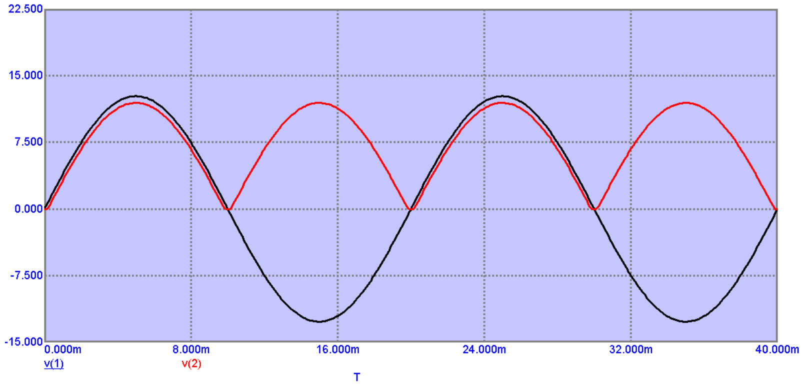


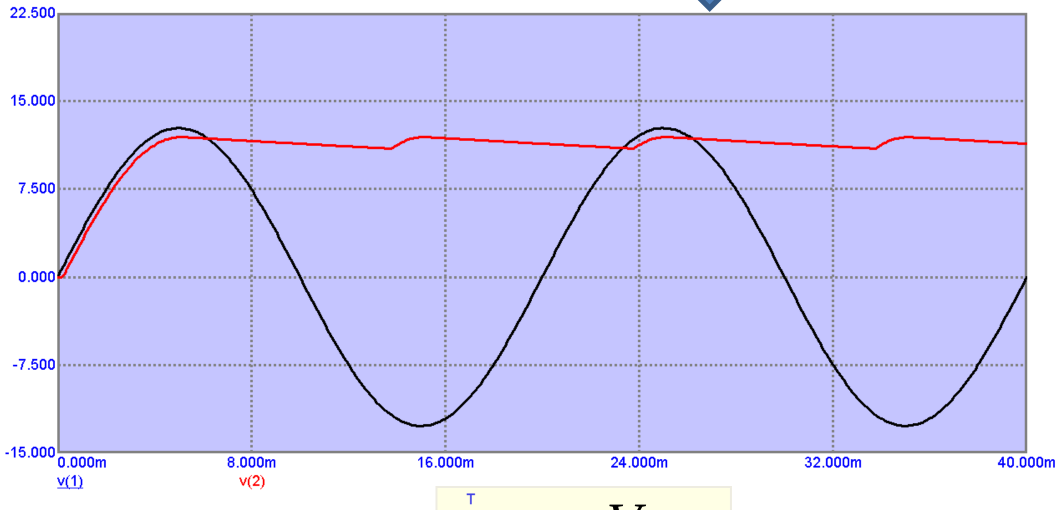
-
+
V_S
D4
D1
R_L
V_O
D3
D2

Power supply using full wave Rectifier





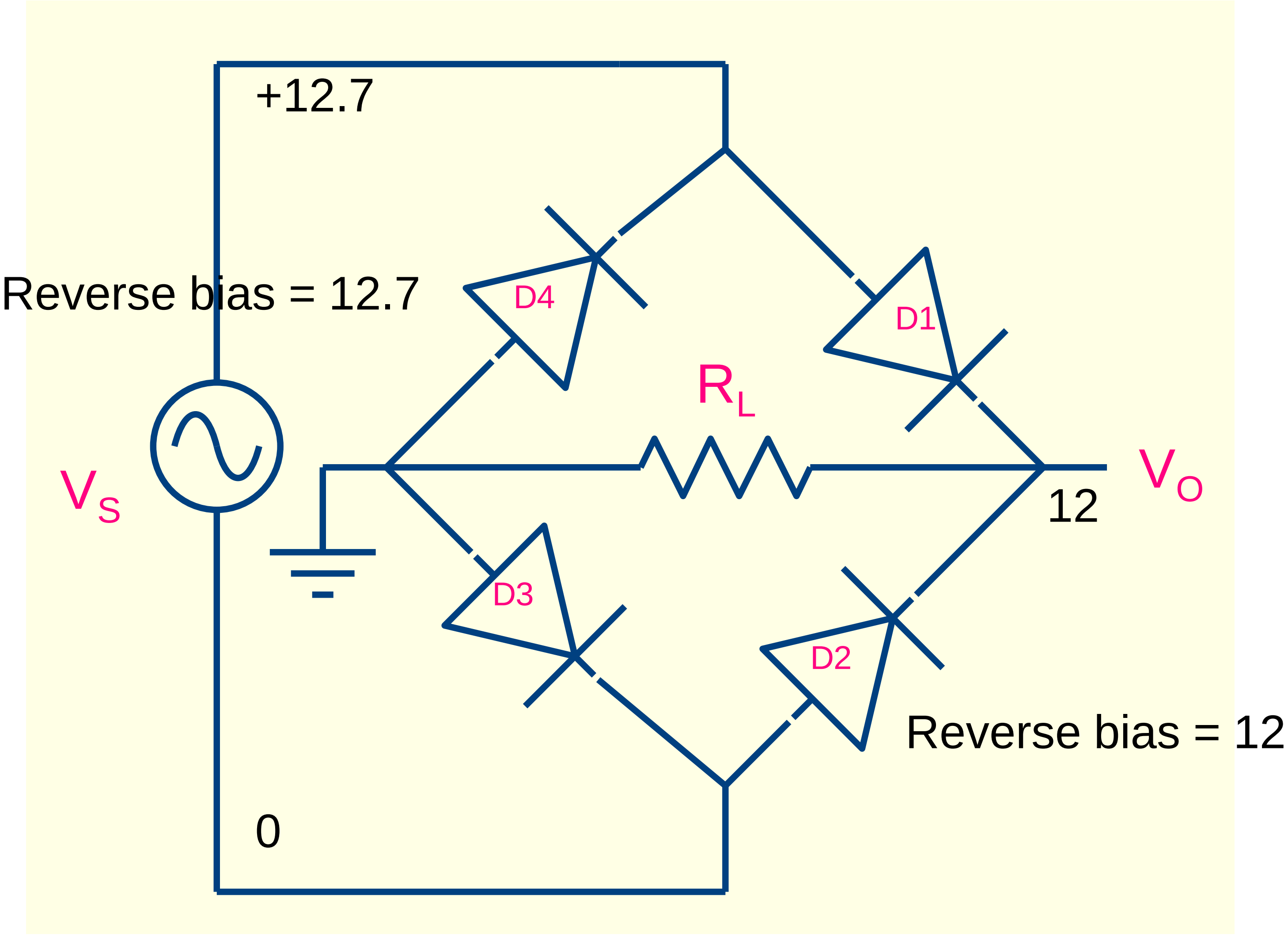




$$V_r \cong \frac{V_M}{2\, f R_L C}$$

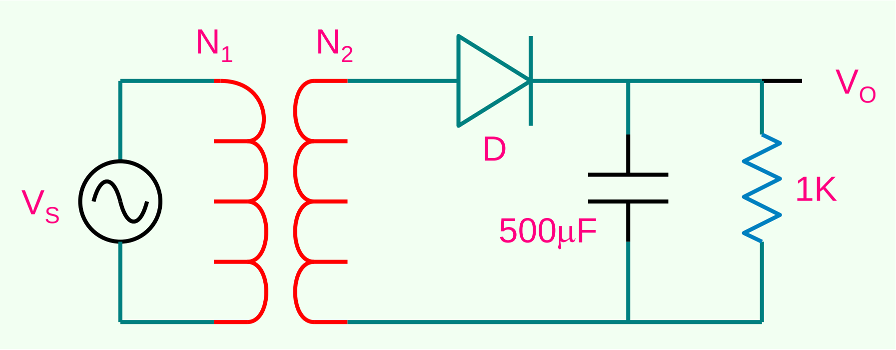
Ripple is smaller in full wave rectifier based power supply

Peak Inverse Voltage

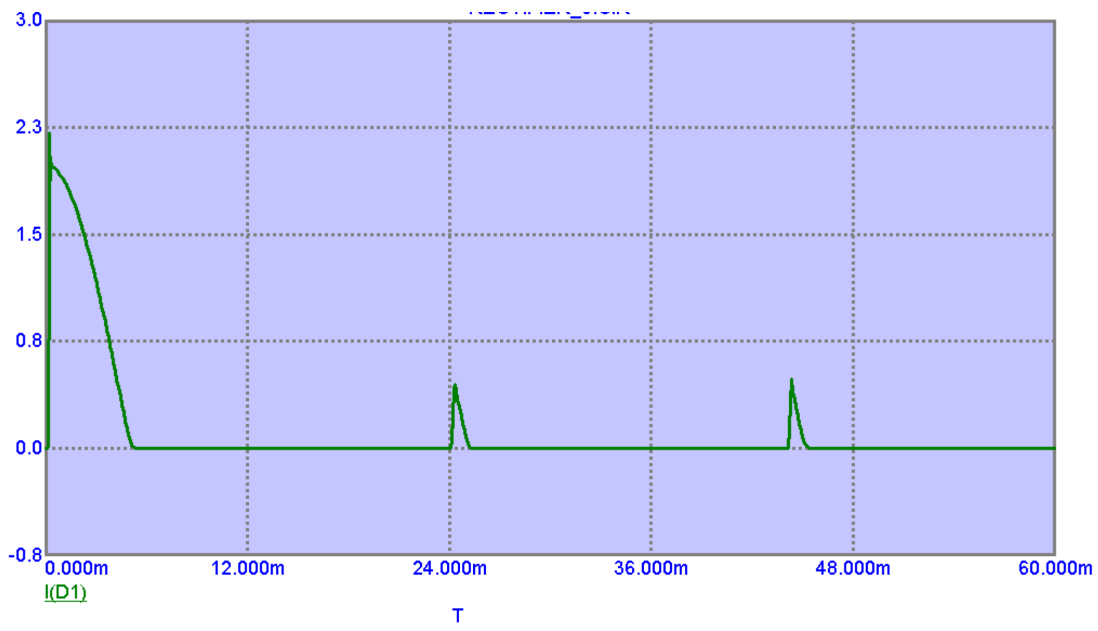


$$PIV \cong v_O + 0.7$$

Reducing Ripple to a very small value is not easy !

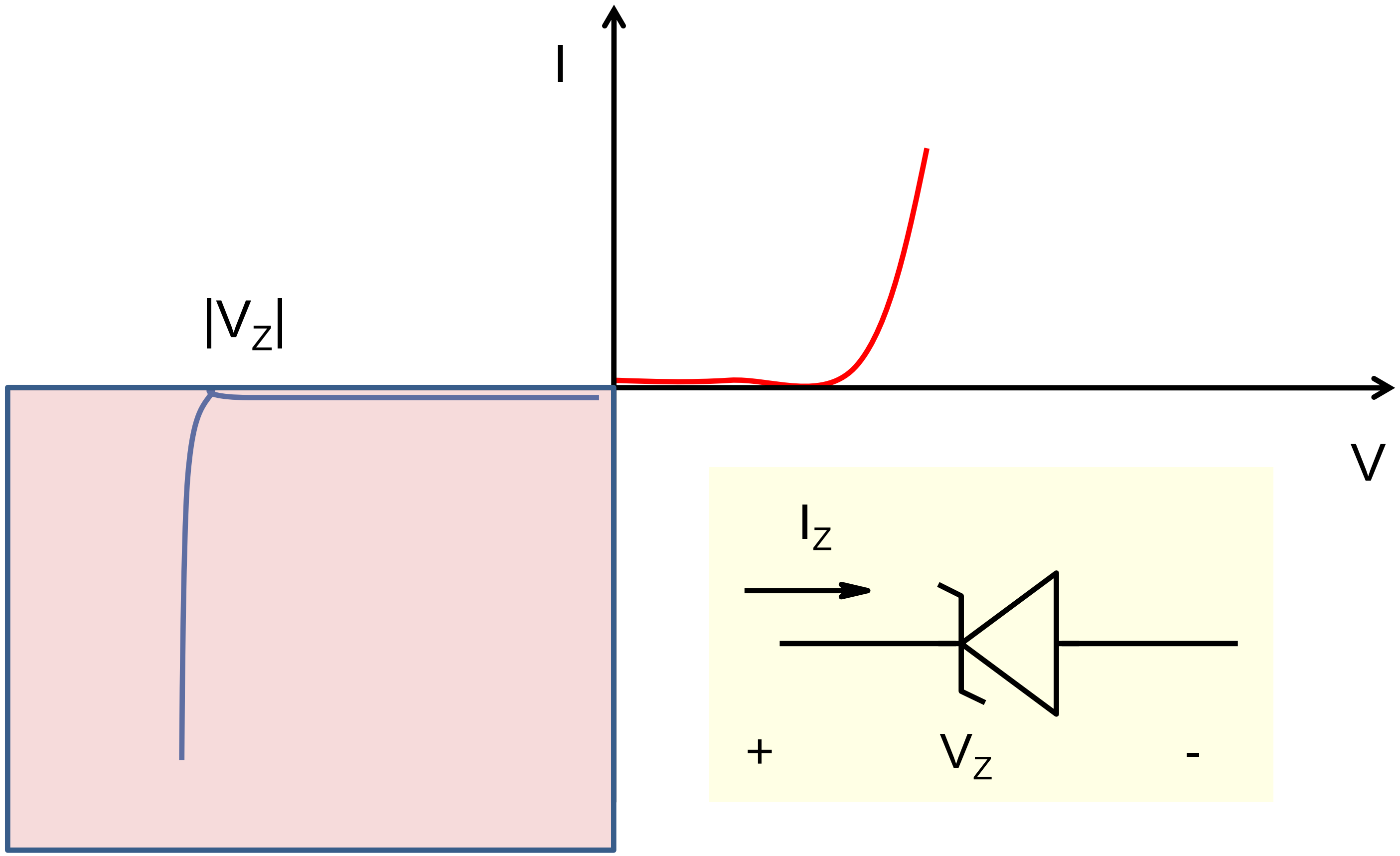


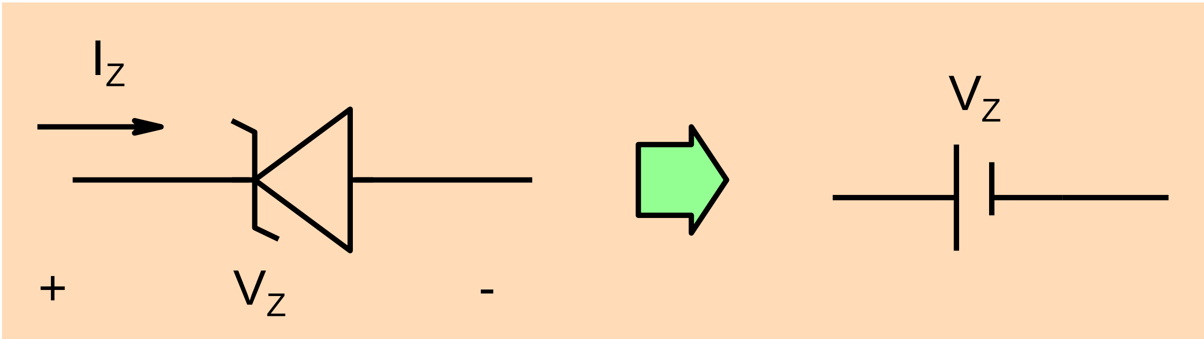
$$V_r = 0.438V$$



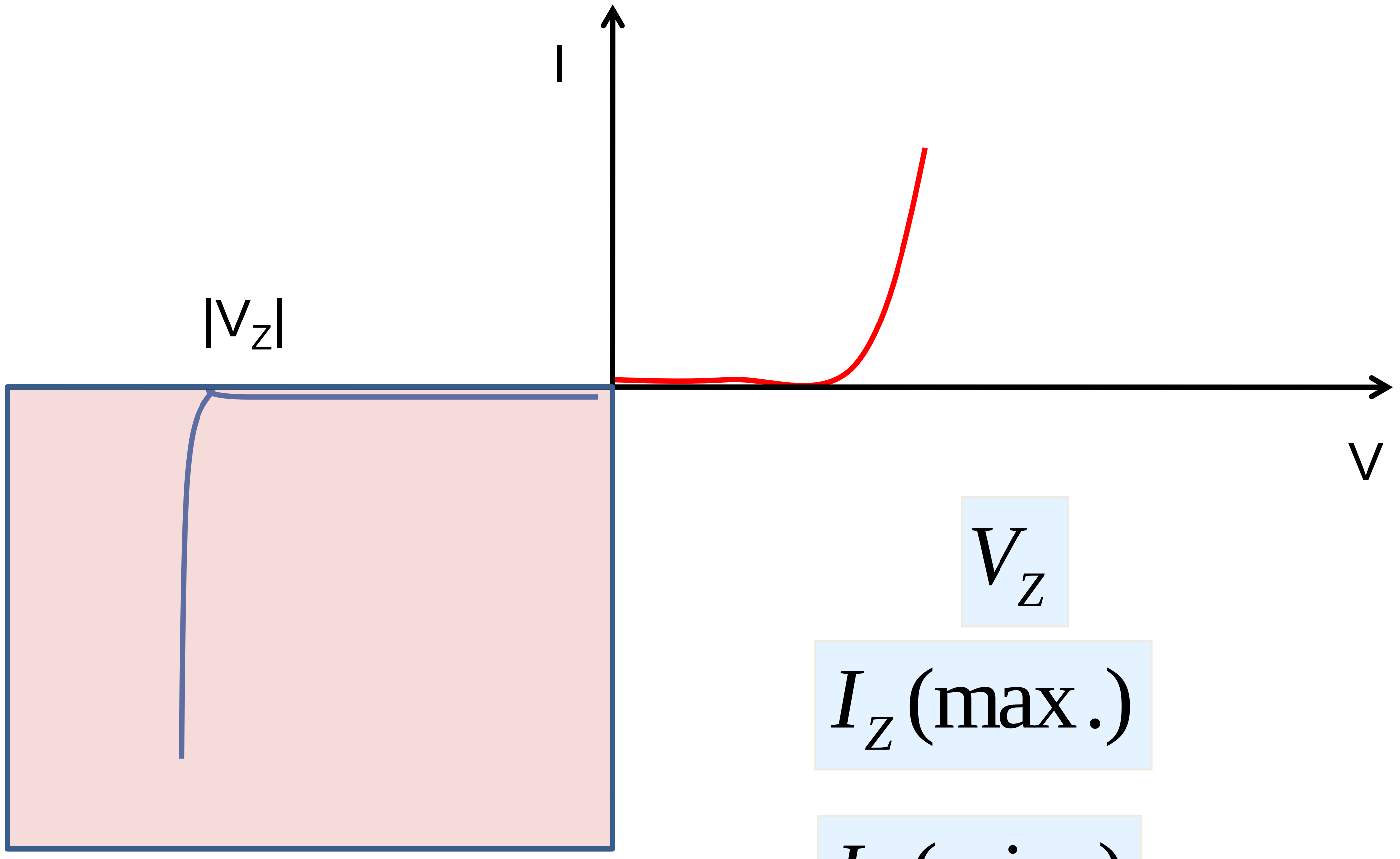
Zener Diode

A diode specially designed to operate in reverse bias in ‘breakdown’ region





Zener diode: Important Characteristics

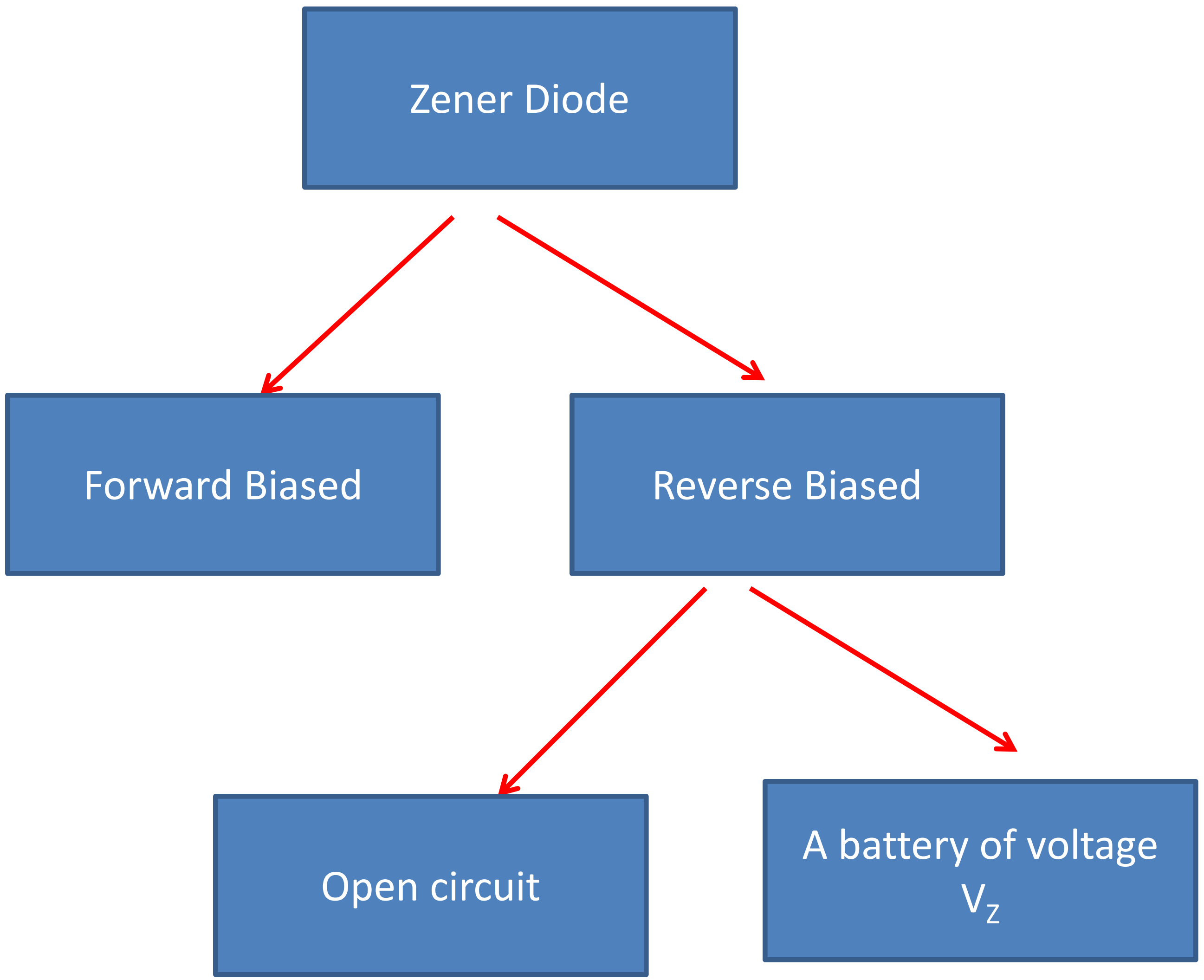


V_Z

$I_Z(\text{max.})$

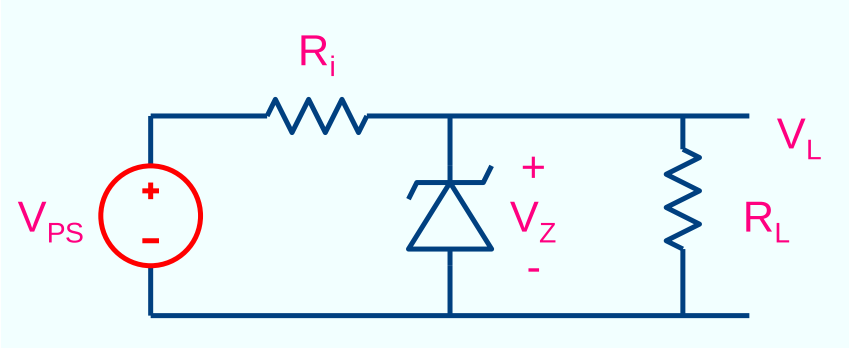
$I_Z(\text{min.})$

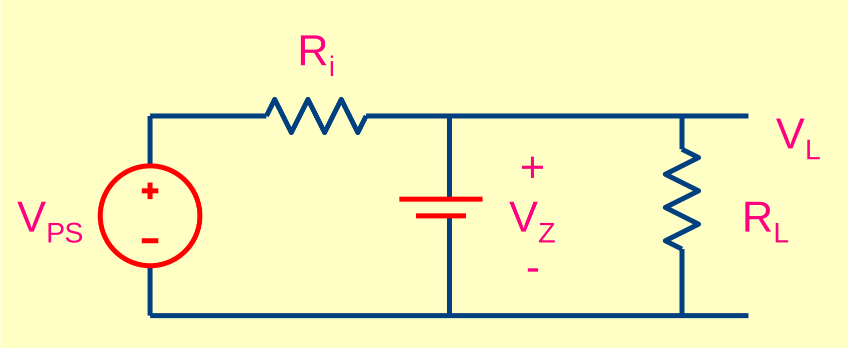
P_Z

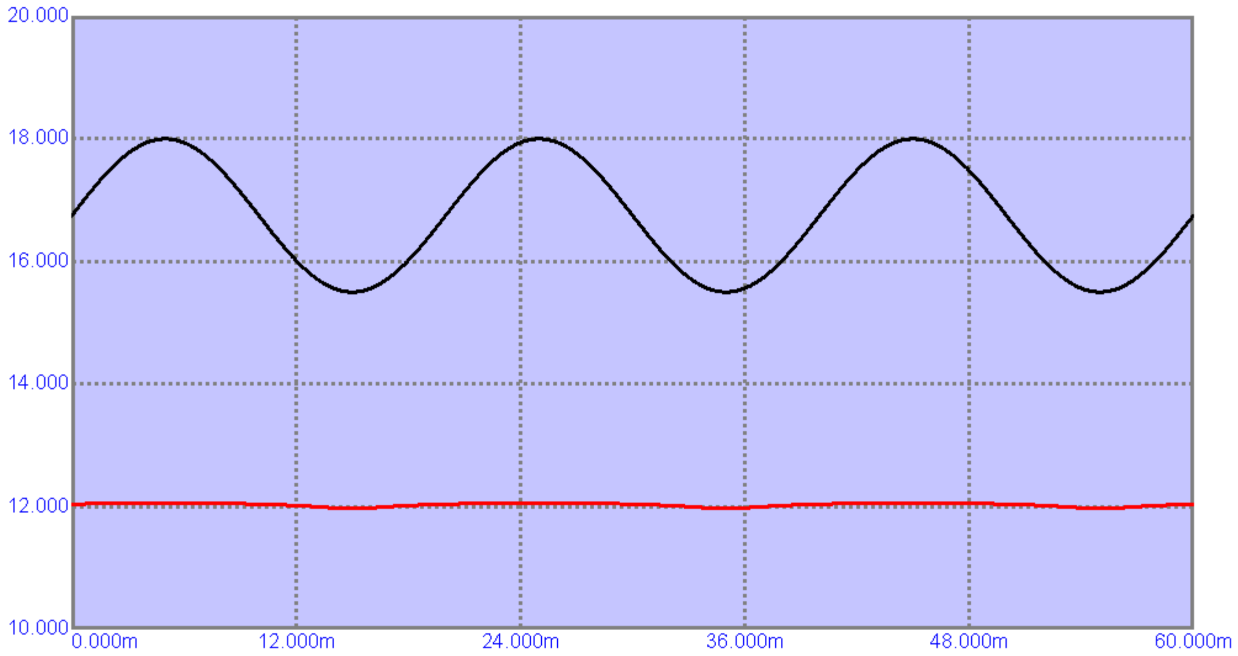


Zener Diode
Forward Biased
Reverse Biased
Open circuit
A battery of voltage V_Z

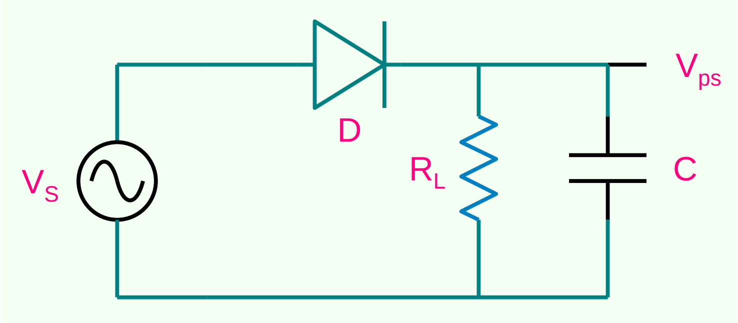
Voltage Reference Circuit

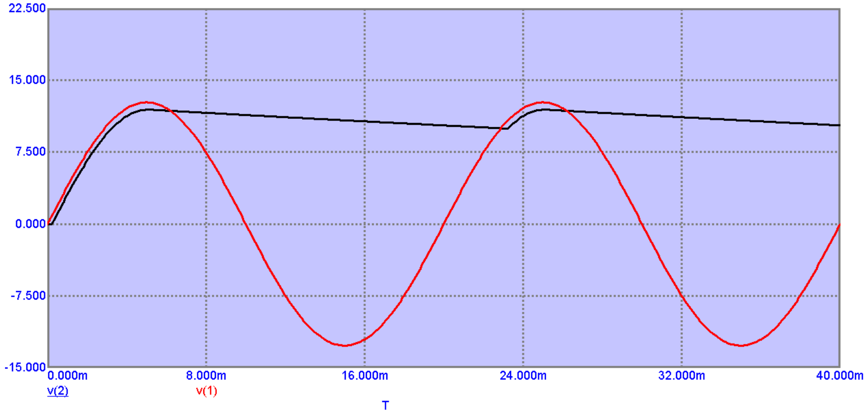


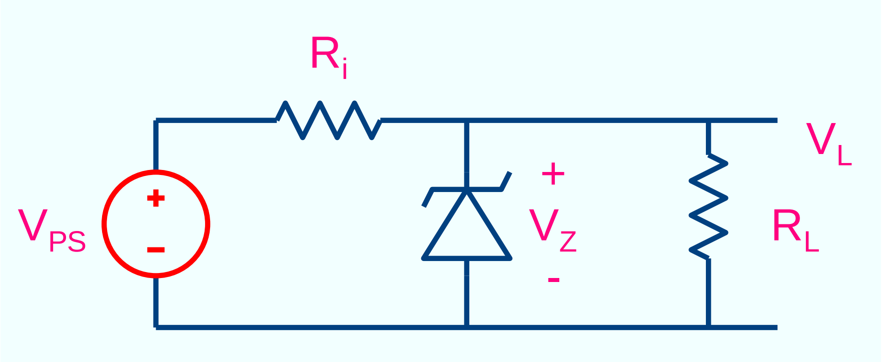


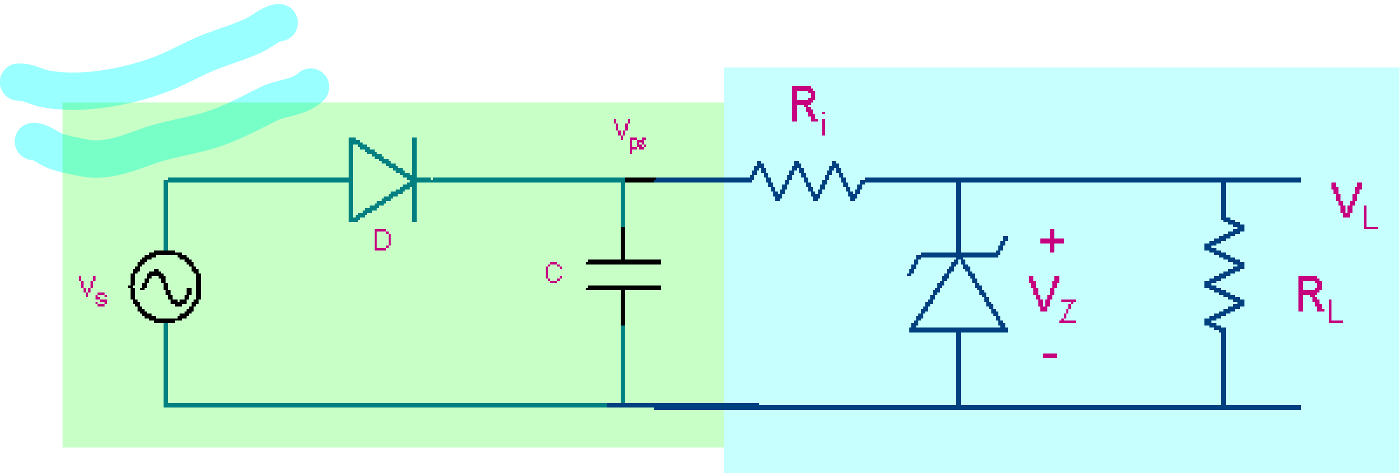


Power supply with regulator

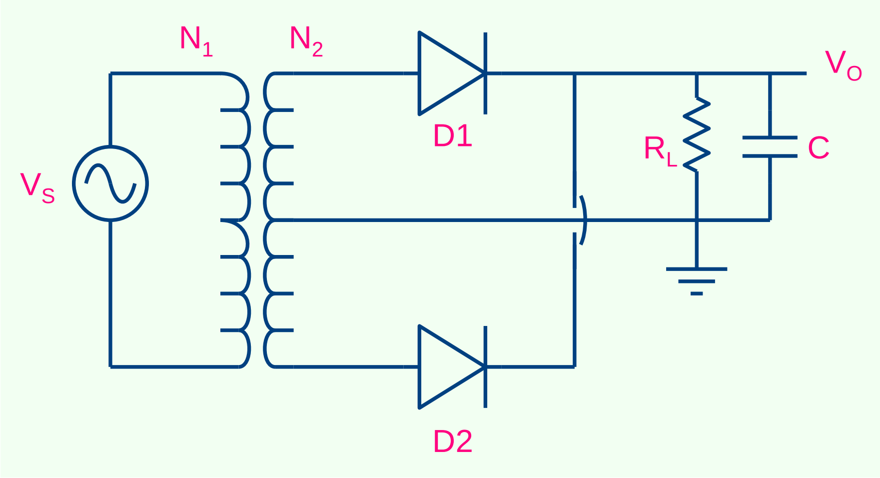


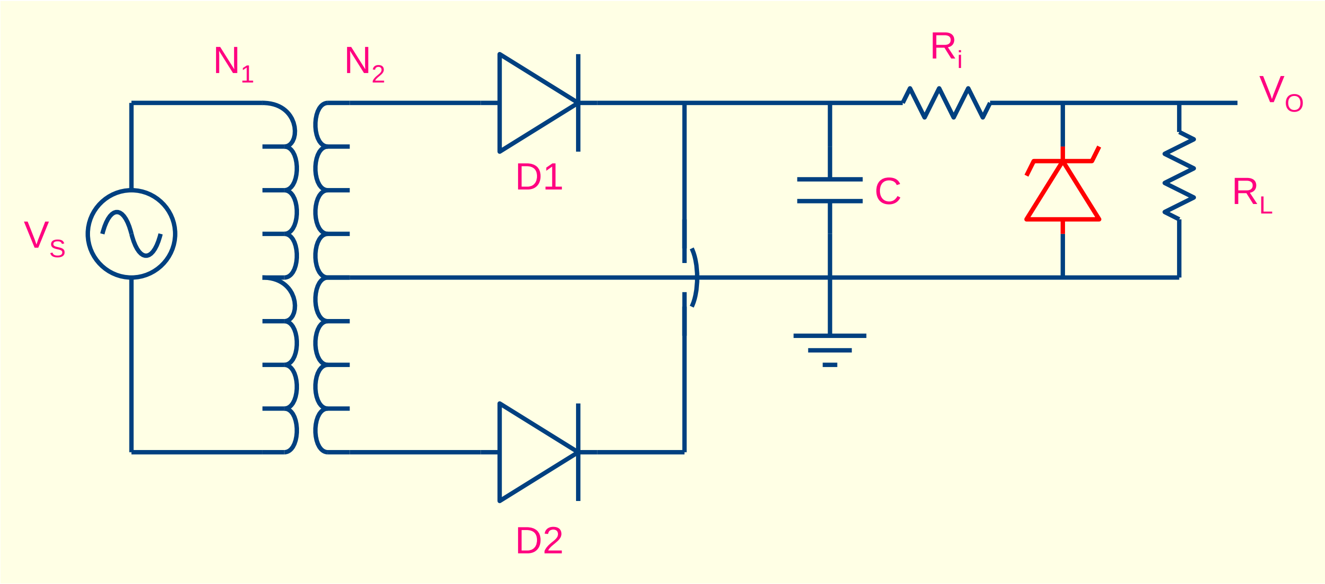


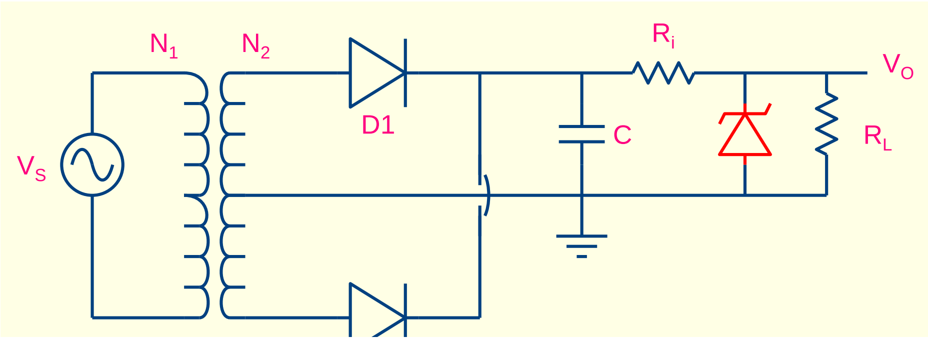




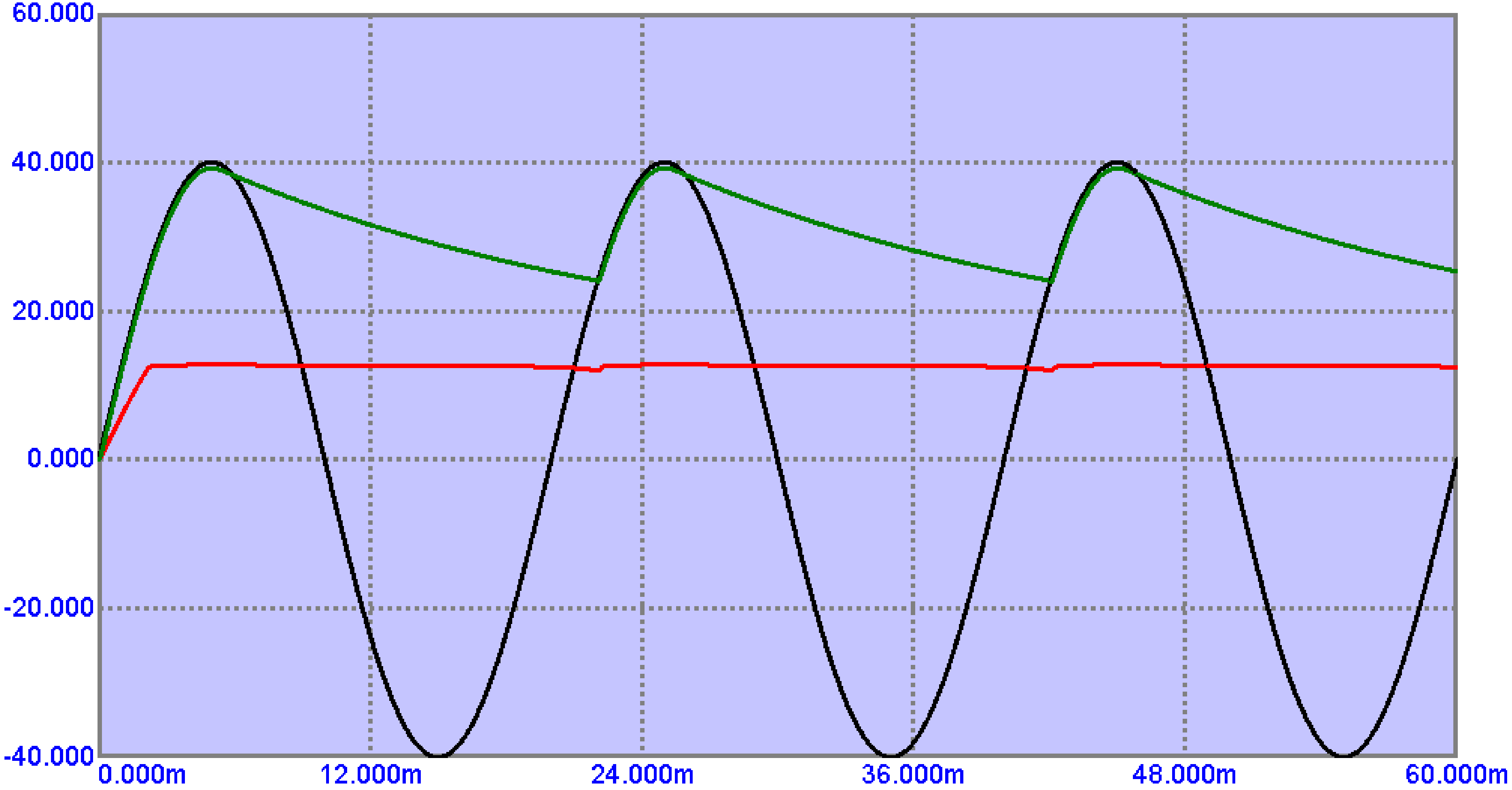
Zener diode as Voltage Regulator





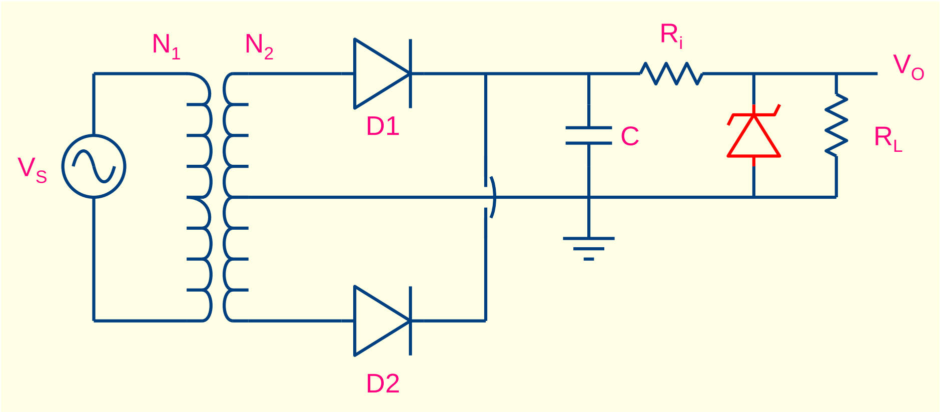


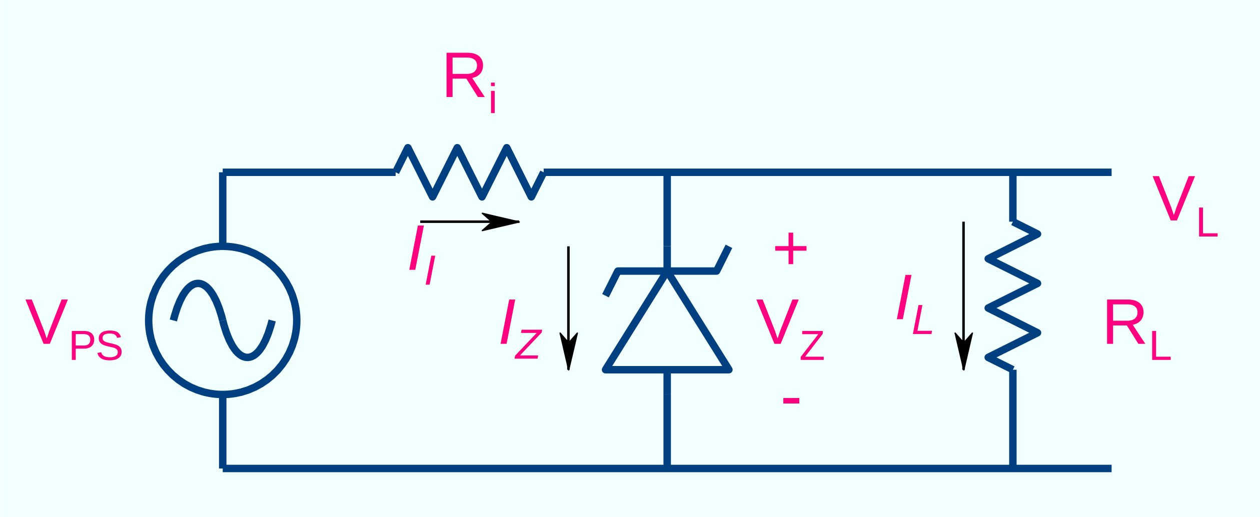
N1
N2
D1
Ri
VO
VS
C
RL



60.000
40.000
20.000
0.000
-20.000
-40.000
0.000m
12.000m
24.000m
36.000m
48.000m
60.000m

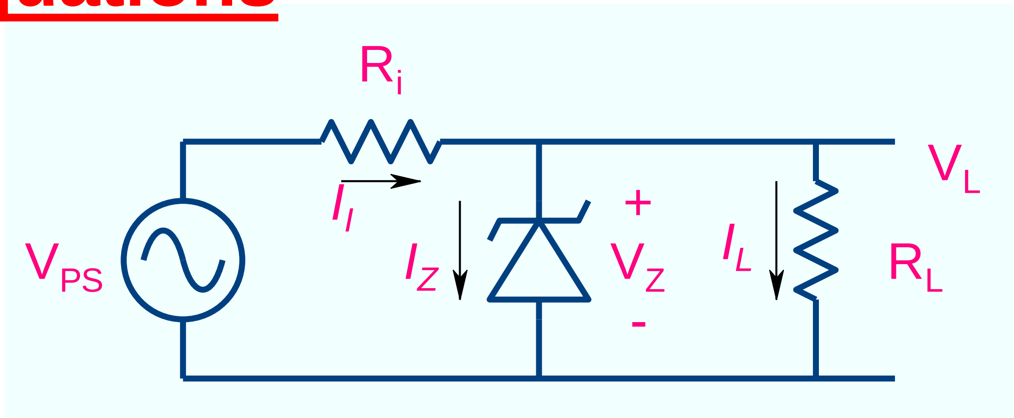
Voltage Reference Circuit





Design Problem: Determine R_i and zener diode specifications such that output voltage is +12V, load current can vary between 0 to 0.1A. The input voltage may vary between 18 to 15.5V.

Voltage Reference Equations



$$I_i = \frac{V_{PS} - V_Z}{R_i} = I_Z + I_L$$

$$I_Z = \frac{V_{PS} - V_Z}{R_i} - I_L$$

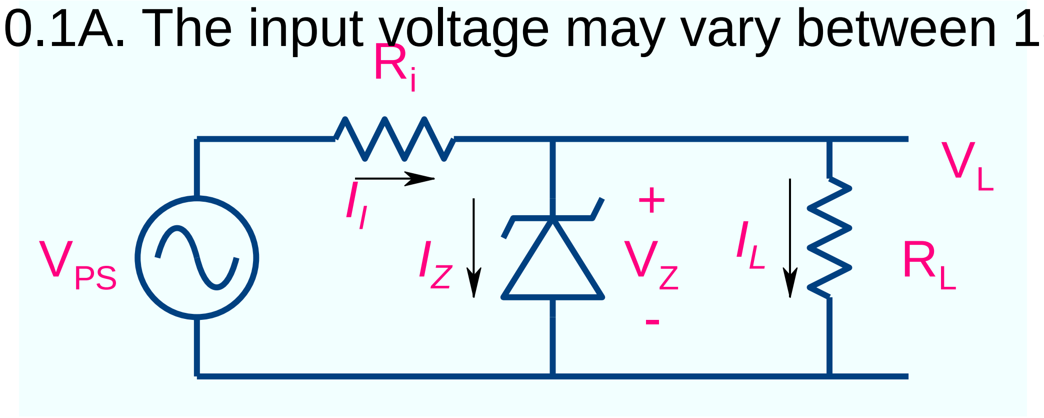
$$I_{Z\max} = \frac{V_{PS\max} - V_Z}{R_i} - I_{L\min}$$

$$I_{Z\min} = \frac{V_{PS\min} - V_Z}{R_i} - I_{L\max}$$

$$P_{Z\max} = V_Z I_{Z\max}$$

Check correctness of design by checking compliance with Zener diode ratings

Design Problem: Determine R_i and zener diode specifications such that output voltage is +12V, load current can vary between 0 to 0.1A. The input voltage may vary between 18 to 15.5V.

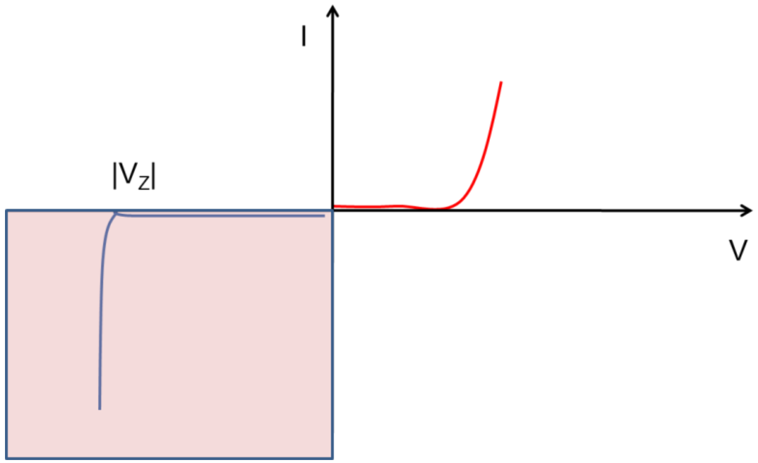


$$I_i = \frac{V_{PS} - V_Z}{R_i} = I_Z + I_L$$

$$I_Z = \frac{V_{PS} - V_Z}{R_i} - I_L$$

$$I_{Z\max} = \frac{V_{PS\max} - V_Z}{R_i} - I_{L\min}$$

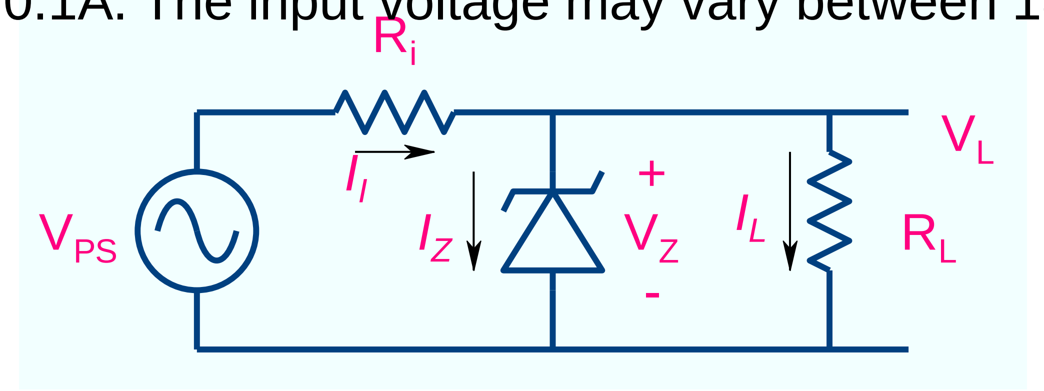
$$I_{Z\min} = \frac{V_{PS\min} - V_Z}{R_i} - I_{L\max}$$



$$R_i = 40\Omega \Rightarrow I_{Zmax} = 0.15A; I_{Zmin} = -0.013A$$

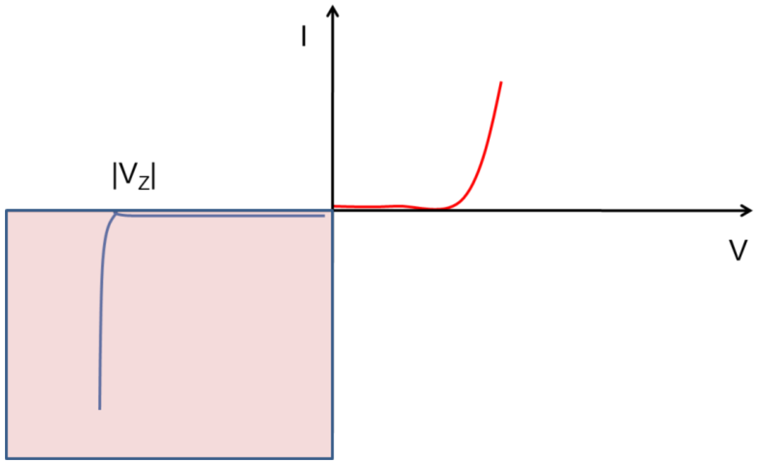
$$R_i = 10\Omega \Rightarrow I_{Zmax} = 0.6A; I_{Zmin} = 0.25A$$

Design Problem: Determine R_i and zener diode specifications such that output voltage is +12V, load current can vary between 0 to 0.1A. The input voltage may vary between 18 to 15.5V.



$$I_i = \frac{V_{PS} - V_Z}{R_i} = I_Z + I_L$$

$$I_Z = \frac{V_{PS} - V_Z}{R_i} - I_L$$



$$I_{Z\max} = \frac{V_{PS\max} - V_Z}{R_i} - I_{L\min}$$

$$I_{Z\min} = \frac{V_{PS\min} - V_Z}{R_i} - I_{L\max}$$

$$\frac{I_{Z\max}}{I_{Z\min}} \cong 10$$

$$R_i = \frac{V_{PS\min} - 0.1 V_{PS\max} - 0.9 V_Z}{I_{L\max}}$$

$$P_{Z\max} = V_Z I_{Z\max}$$

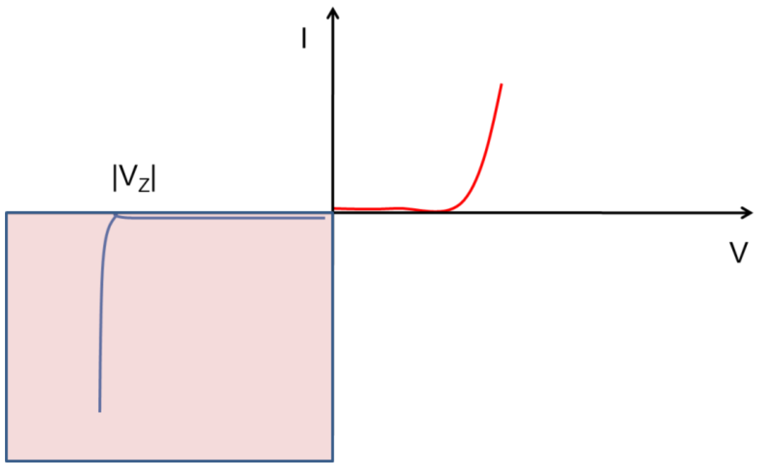
Design Problem: Determine R_i and zener diode specifications such that output voltage is +12V, load current can vary between 0 to 0.1A. The input voltage may vary between 18 to 15.5V.

$$R_i = \frac{V_{PS\min} - 0.1V_{PS\max} - 0.9V_Z}{I_{L\max}} = 29\Omega$$

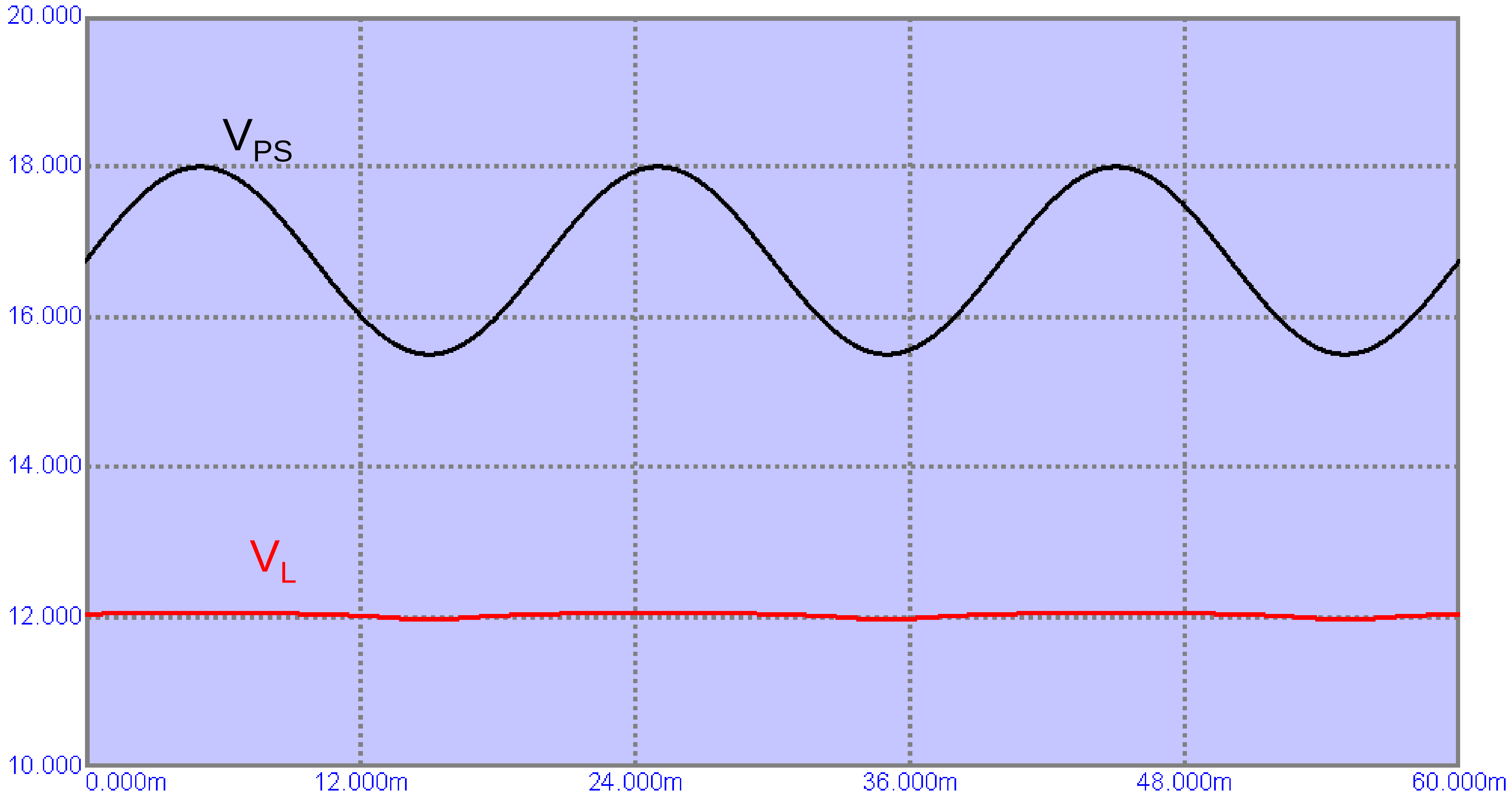
$$I_{Z\max} = \frac{V_{PS\max} - V_Z}{R_i} - I_{L\min} = 0.207A$$

$$I_{Z\min} = \frac{V_{PS\min} - V_Z}{R_i} - I_{L\max} = 0.0207$$

$$P_{Z\max} = V_Z I_{Z\max} = 2.48W$$



Check the design through simulations



20.000
18.000
16.000
14.000
12.000
10.000
0.000m
12.000m
24.000m
36.000m
48.000m
60.000m
V_{PS}
V_L

Design Problem-2: Determine R_i and zener diode specifications such that output voltage is +12V, load current can vary between 0 to 0.1A. The input voltage may vary between 15 to 12.915V.

$$R_i = \frac{V_{PS\,\min} - 0.1V_{PS\,\max} - 0.9V_Z}{I_{L\,\max}} = 6.1\Omega$$

$$I_{Z\,\max} = \frac{V_{PS\,\max} - V_Z}{R_i} - I_{L\,\min} = 0.488A$$

$$I_{Z\,\min} = \frac{V_{PS\,\min} - V_Z}{R_i} - I_{L\,\max} = 0.049$$

$$P_{Z\,\max} = V_Z I_{Z\,\max} = 5.85W$$